

High-pressure injection injury: a case report and systematic review

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ABSTRACT

High-pressure delivery devices for paint and other substances can lead to severe injuries of the hand without immediate surgical debridement. We present a case of a high-pressure paint gun injury treated surgically with full resolution of function. A systematic review of the literature details outcomes of similar injuries.

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Introduction

Injections from high-pressure, airless paint-guns are uncommon industrial accidents that may result in acute injuries, usually to the nondominant hand [1]. They may appear innocuous because of the small size of the entrance wound. These injuries commonly require emergent management including immediate surgical debridement to avoid tissue necrosis and loss of hand function [2]. Successful treatment of this injury hinges on early recognition and intervention [3]. Delayed treatment can result in irreversible soft tissue damage, lifelong morbidity, and even amputation. Rarely oleogranulomas, fibrohistiocytic tumours and squamous cell carcinoma have been described as late complications [1,4–7]. We present a case of paint gun injury that was successfully debrided and managed with full return of function.

Illustrative case

A healthy 57-year-old-male painter presented to urgent-care with a pinpoint entrance wound (Figure 1) on the radial aspect of the right long finger middle phalanx from a pressurised latex paint sprayer. Radiographs were obtained (Figure 2). Operative exploration involved exposure of the neurovascular bundles and flexor sheath of the finger (Figure 3) and debridement. The fresh paint was removed with saline irrigation and skin

loosely closed. IV antibiotics and pain control with an infraclavicular block permitted bedside soap and water soaks for 48 h postoperatively. He had complete return of sensation with normal range of motion post latex paint evacuation. Skin edges were loosely approximated, and the finger healed by secondary intention. Hand therapy was performed as per institutional protocol.

Methods

A review of the pertinent literature was performed using a search on the National Institute of Health's PubMed database using the key phrases "high-pressure injection injury", "paint gun injury", or "pressure gun injury", inclusive of "hand". The initial search yielded 205 articles. Further inclusion criteria consisting of case reports available in the English language narrowed the search to 83 articles. Additional eligibility criteria including high-pressure injection and injuries pertaining to the hand reduced the available articles to 61 [3–63]. Previous reviews have noted that high-pressure injection of air and water were not associated with the same complications as the injection of other substances and did not generally require surgical treatment, so articles detailing air or water injections were further excluded [8]. This left 49 articles with 115 cases for review. We present a summary of

these case reports, as well as an overview of recent developments in the literature.

Results

Although a rare occurrence, high-pressure injections of the hand have been frequently reported throughout



Figure 1. Entrance wound on the radial aspect of the right long finger middle phalanx.

the literature. The population included in our review was predominantly young men, with an average age of 33% and 96% male. Many described occupations that required usage of high-pressure equipment. The injured hand in the prototypical case is often the patient's non-dominant hand, usually the left hand, due to the gun being operated in the patient's dominant hand. Instances such as leaks along the hose of a high-pressure system caused high-pressure injection to either hand. A unique cohort noted an accidental injection while injecting high-pressure vaccines into livestock, which were to the dorsum of the hand [9].

The most common material injected was paint, in 42% of cases, followed by hydraulic fluid in 17%. The type of paint was not always disclosed, but previous reports have noted an increasing incidence of complications with oil-based paint, rather than water-based [8,10]. Latex paints are increasingly more widely used and would demonstrate a lower risk of amputation than other paints. We recorded a 17% amputation rate of paint injection, which was lower than other caustic substances, but a 35% rate of necrosis. Hydraulic fluid presented a higher infection rate at 50% but a lower amputation and necrosis rate. The most necrotic substances were noted to be dry cleaning solvent, gasoline, and petroleum (Table 1).

The pressure of injection was not widely reported but ranged from 1800 psi to 4350. A pressure of only 100 psi is necessary to penetrate the skin [11]. These pressures can avulse tendons, destroy vasculature, and cause significant neuropathy. Of the 17 cases that noted the injection pressure, pressures over 2500 psi



Figure 2. Radiograph demonstrating foreign material in the volar aspect of the right long finger, extending far beyond the injection site, lateral (left) and AP (right) views.

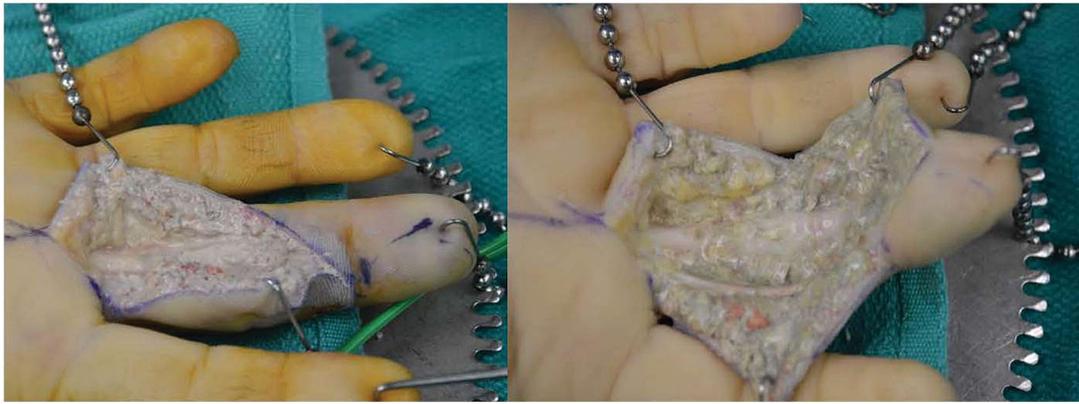


Figure 3. (left) Operative exploration with exposure of the neurovascular bundles and flexor sheath of the finger. The fresh white paint is clearly visible; (right) After extensive washout and initial debridement.

Table 1. Number of cases of each type of injected material.

Material	Number
Dry Cleaning solvent	6
Gasoline, petroleum	5
Grease	9
Hydraulic fluid	18
Paint	48
Paint thinner	10
Vaccine	6
Other	13
Total	115

had higher rates of necrosis and neuropathy but resulted in comparable amputation rates with lower pressures. Interestingly, half of the cases with pressures under 2500 psi developed infections, compared to 14% and no instances in pressures over 2500 and over 3500, respectively.

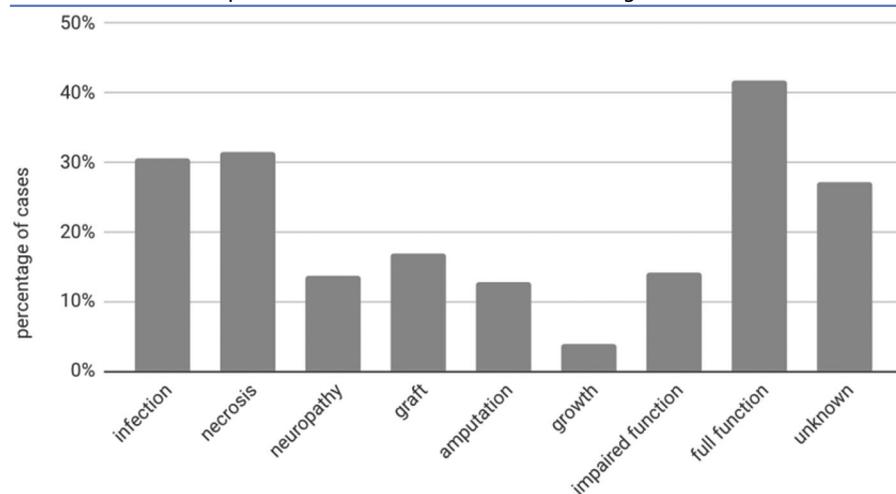
The index finger was the most common site of injection, followed by the long finger. This correlates with the standard mechanism of injury being an accidental discharge of the pressure gun while having one's fingers over the nozzle. While a small number of cases were associated with the thumb, they described higher rates of complications, including infection, neuropathy, and the necessity of a subsequent graft, as well as persistent functional impairment. Index finger injuries reported similar instances of necrosis and amputation as thumb injuries but were less likely to report functional impairment, particularly after amputation. The material injected has been noted to follow the neurovascular structures when injected into the digits.

The time between injury and surgery has been known to correlate with severity of symptoms. Within the reviewed cases, time at presentation varied from within 1 h–6 years. When the outliers of 6 months, 2 years, and 6 years were omitted from the calculation, the average time of presentation was 34 h. Often, the patients complained of little to no pain upon injection,

with a small injection injury. Several presented to the emergency room and were discharged with antibiotics and tetanus boosters without recognition of the need for surgical debridement. These patients generally develop more severe symptoms within 24 h that prompt them to return to the emergency room, at which point the urgency for debridement is recognised, and many can receive digit-preserving treatment.

After debridement, one-third of the patients experienced necrosis, a natural progression of the injury pattern, and one-third exhibited signs of infection. High-pressure injuries often require multiple debridements, which is further complicated by the need to treat infection or necrosis. Neuropathy was associated in fewer cases but with all of the reported injection areas in the hand, and often with residual pain or strength impairment. Grafts were warranted in 17% of cases to restore perfusion to the affected area. We report an overall amputation rate of only 13%, indicating that amputation may be less common than previously reported. Index finger and thumb injuries were associated with the highest rates of amputation at 34% and 38%, respectively. Patients reported resolution of symptoms and adequate functionality of the hand in 42% of cases (Table 2).

While few cases reported long-term follow-up, several cases involved long-term complications of high-pressure injuries. Three reports included cases of fibrohistiocytic tumour and three detailed granuloma formation. Two of the patients reported adequate surgical debridement within a couple of days after injury, but the rest did not seek or receive proper treatment at the time. All of these patients reported increasing pain and swelling at the site of injury, and the masses were excised under surgical exploration of the site. Some patients that had long-term follow up also reported a residual loss of strength in the affected hand.

Table 2. Rate of complications of each case and the resulting outcomes.

Discussion

High-pressure injection injuries are catastrophic due to both the mechanical force of injection and the introduction of caustic substances into the tissue. Those operating these types of high-pressure delivery devices are often those working in painting, mechanics, and farming [12]. The population affected is predominantly young men who accidentally discharge a pressure gun while cleaning the equipment or test the gun by placing a finger in front of the nozzle, as commonly practiced with low-pressure equipment [12]. Most patients describe a benign presentation with little pain or indication of severe trauma. This can lead to dangerous delaying of medical treatment, either by the patient themselves not seeking treatment or the dismissal of patients from the emergency room by providers not familiar with this type of injury.

Of additional concern is the ability of the substance, combined with the subsequent oedema and swelling, to cause a compartment-like syndrome of the affected space, leading to increased pain and impaired functionality of the hand over time without treatment. This can result in further damage from resulting vasospasm, thrombosis, and ischaemia [13]. The more caustic substances have the potential to raise a stronger inflammatory response, further increasing the depth of injury to the tissue.

The standard of care for high-pressure injection injuries includes administration of antibiotics, tetanus prophylaxis, and immediate recommendation for surgical debridement. Third generation cephalosporins are often commonly administered [14]. Radiographs can be helpful in located the foreign material in some circumstances, and patients may demonstrate an elevated white blood cell count a few hours after injury

[11]. As stated earlier, air and water injection injuries can be treated conservatively without immediate surgical debridement but should be monitored closely to avoid progression to compartment syndrome or other emergent complications [8]. Injuries from animal vaccine injection can also be monitored without immediate surgical intervention if the doses are less than 0.5 mL. These injuries are specifically at risk for developing infections and inflammatory response to the vaccine components, so they must be monitored appropriately [15]. Corticosteroids have been utilised to dampen the inflammatory response after high-pressure injection injuries with varied results and no clear consensus on its efficacy, warranting further investigation [11]. Additionally, a recent cohort utilised vacuum therapy to treat high-pressure injection injuries and found positive results in decreasing tissue oedema and the further spread of injected substances throughout the tissue [16].

Wong et al. suggested a treatment plan based on the severity classification of the high-pressure injection. Mild cases with low-risk factors can be observed closely with antibiotics, while moderate risk cases should proceed directly to surgical debridement with delayed closure. Severe cases included injection of paint or caustic substances, very high-pressure injections, injuries with loss of sensation or circulation, and delayed patient presentation. In these cases, repeated debridements staged amputations, and flap reconstruction should all be considered as potential treatment options [17]. A wide incision upon debridement is generally recommended to remove all necrosed tissue and as much of the foreign substance as possible, then to observe the patient radiographically and symptomatically to determine if further surgical exploration is warranted

[16]. Patients should be educated on the potential of amputation and late complications that may present after this type of injury.

Previous cohort studies with significant follow up have noted diminished sensation and two-point discrimination at the fingertips in all patients with digital injuries. Patients often heal gradually with significant flexion impairment and necessitate physiotherapy [19]. While manageable functionality and return to work are undoubtedly possible after high-pressure injuries, patients should be aware of the long recovery process and risk of persistent complications. It should be expected that patients will exhibit some residual strength impairments in the affected hand or digit. In one cohort, only 43% of followed patients were able to return to their previous employment [20]. Proper education on the safe operative usage of high-pressure equipment and the need for immediate medical treatment upon injury is imperative, as it could decrease the rates of injury and cases of delayed presentation. As providers are increasingly more aware of proper management in the emergency room and upon surgical intervention, patients may more commonly recover without significant long-term repercussions from high-pressure injection injuries.

Disclosure statement

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